Original Article

Implementation of a telestroke system for general physicians without a nearby stroke center to shorten the time to intravenous thrombolysis for acute cerebral infarction

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Aim: We aimed to establish a telestroke system for general physicians in areas without a nearby stroke center and investigate its usefulness for recombinant tissue plasminogen activator (rt-PA) therapy for patients with acute cerebral infarction.

Methods: We used a hub and spoke model, in which a hub hospital provided telestroke support to the spoke hospitals in rural areas that were not nearby a stroke center. The telestroke support device enabled the sharing of images and real-time face-to-face discussion with a stroke specialist for diagnosis and treatment. We evaluated the effect of this telestroke system on shortening time to start rt-PA therapy.

Result: One hub and three spoke hospitals were selected. From May 2017 to November 2018, seven patients (77.2 ± 6.3 years old) suspected to have acute cerebral infarction were treated at the spoke hospitals via this system, three of whom received intravenous rt-PA administration by a general physician under telestroke support. If these patients would have been sent via ground ambulance to the nearby stroke center, it would have taken approximately 48 min more to administer rt-PA.

Conclusion: Establishment of a telestroke support system for general physicians in areas without a nearby stroke center was useful for promptly performing rt-PA therapy.

Key words: Acute cerebral infarction, general physician, information and communication technology, prognosis, telemedicine

INTRODUCTION

FOR TREATMENT OF acute cerebral infarction, thrombolytic therapy with intravenous administration of recombinant tissue plasminogen activator (rt-PA), which is recommended for grade A severity in the related guidelines, within 4.5 h of onset has been shown to improve prognosis.[1–3] The guidelines also recommend endovascular thrombectomy using a stent retriever for acute cerebral infarction in patients with major trunk of middle cerebral artery or internal carotid artery, which when performed within 6 h of onset has also been shown to improve prognosis.[4–6] Therefore, to improve the prognosis of patients with acute cerebral infarction, physicians, after performing an initial examination/treatment, must quickly decide whether to transfer the patient to a stroke center for rt-PA therapy or perform an endovascular thrombectomy. A stroke telemedicine (i.e., telestroke) system has been established to support physicians during this process.[7–9] In Japan, prevention and treatment measures for stroke were legislated in December 2018,[10] and the Japanese Society of Stroke recently began to establish primary stroke centers, where rt-PA therapy to be administered by a stroke specialist is always available. However, the number of primary stroke centers is limited in rural areas, such as Miyazaki Prefecture, increasing the need for a telestroke system.

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Most telestroke systems that are currently used in Japan are intended to support neurosurgeons or neurologists who do not specialize in stroke. However, in rural areas such as Miyazaki Prefecture, the number of neurosurgeons and neurologists is also limited. In such situations, general physicians, regardless of specialty, who accept patients with acute cerebral infarction, need to be able to perform rt-PA therapy as soon as possible to improve the prognosis of the patients. To encourage these physicians to perform rt-PA therapy without delay and remove some of the risk, the implementation of telestroke support is needed also from the medical safety viewpoint. For these reasons, we established a new type of telestroke support system for use by general physicians in areas where a stroke center is not nearby. Most of the currently used telestroke devices only share images and blood test data, and discussions are performed through typed characters (e.g., text). However, general physicians who are presented with patients with acute cerebral infarction may have concerns about the evaluation of symptoms, diagnosis, and treatment, and may be eager to discuss their concerns with stroke specialists face-to-face. Therefore, in our system, both a thin client viewer system and a video camera were installed in the same mobile device (iPad mini), allowing a stroke specialist at a stroke center to review not only the computed tomography (CT) images, but also the symptoms of the patient and rt-PA treatment, and then provide face-to-face advice in real time. The establishment of this telestroke support system in areas with shortages of neurosurgeons and neurologists is an important tool for encouraging general physicians to perform rt-PA therapy without delay, which may improve the prognosis of patients with acute cerebral infarction. In this paper, we report the innovative development of a telestroke device for general physicians and its effect on starting rt-PA therapy without delay.

METHODS

THIS STUDY WAS approved by the Ethics Committee of the University of Miyazaki Hospital.

Selection of "hub" and "spoke" hospitals for the telestroke support system

We used a "hub" and "spoke" model for our telemedicine system, where "hub" hospitals were those providing telestroke support and "spoke" hospitals were those receiving support. We selected "hub" hospitals according to the following criteria being available at all times: one or more stroke specialists, CT and magnetic resonance imaging scanners, and both rt-PA therapy and endovascular therapy. "Spoke" hospitals were selected based on the following criteria: an emergency hospital in the area, the hospital accepted patients with acute cerebral infarction, a CT scanner was available, there was no stroke specialist in the hospital, and there was no nearby stroke center in the area.

New telestroke system for general physicians

We used an iPad mini (Apple Inc, Cupertino, CA, USA) installed with a thin client viewer system called Synapse Zero (FUJIFILM Medical Co. Ltd., Tokyo, Japan) and Face Time (Apple Inc), a video call system (Fig. 1). Because our telestroke system was targeted for general physicians (non-stroke specialists), a videophone system was thought to be an indispensable aspect of support. For internet security, we used a virtual private network for image transmission.

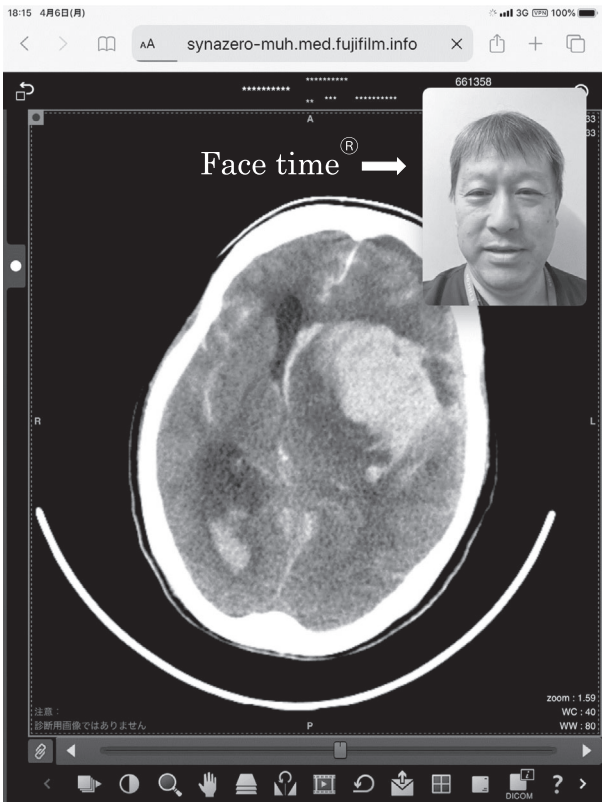

Fig. 1. Telemedicine device. We used iPad minis (Apple Inc) installed with a thin client viewer system called Synapse Zero (FUJIFILM Medical Co. Ltd.) and the video call system Face Time (Apple Inc), which allowed specialists at the "hub" hospital to review computed tomography images, assess the patient, and make recommendations face-to-face in real time.

Telestroke support procedure

We determined that the main indications of initiating the telestroke support system were (i) a patient with an acute cerebral infarction within 4.5 h of onset, and (ii) the general physician in the "spoke" hospital was uncertain about the indication of rt-PA or endovascular thrombolysis therapy. The process to initiate and use the system followed a typical sequence of events. First, the "spoke" hospital would send the CT images of the patient to the "hub" hospital via Synapse Zero. Second, the general physician called the stroke specialist at the "hub" facility for consultation. Third, the stroke specialist at the "hub" hospital reviewed the CT images. Fourth, the stroke specialist called the general physician using Face Time on the iPad mini, double checked the patient's symptoms and National Institutes of Health stroke scale (NIHSS) score,[11] and recommended rt-PA administration or endovascular thrombectomy. If the general physician in the "spoke" hospital decided to administer rt-PA by himself or herself, the stroke specialist verified the doses of rt-PA and oversaw the procedure (Fig. 2). All staff in the "spoke" hospital involved in the diagnosis and treatment of patients with acute cerebral infarction, such as general physicians, emergency nurses, and radiologists, received an average of two simulations as to how to use the system. In addition, they were encouraged to take the "Immediate Stroke Life Support" course (established by the Japan Congress of Neurological Emergencies).

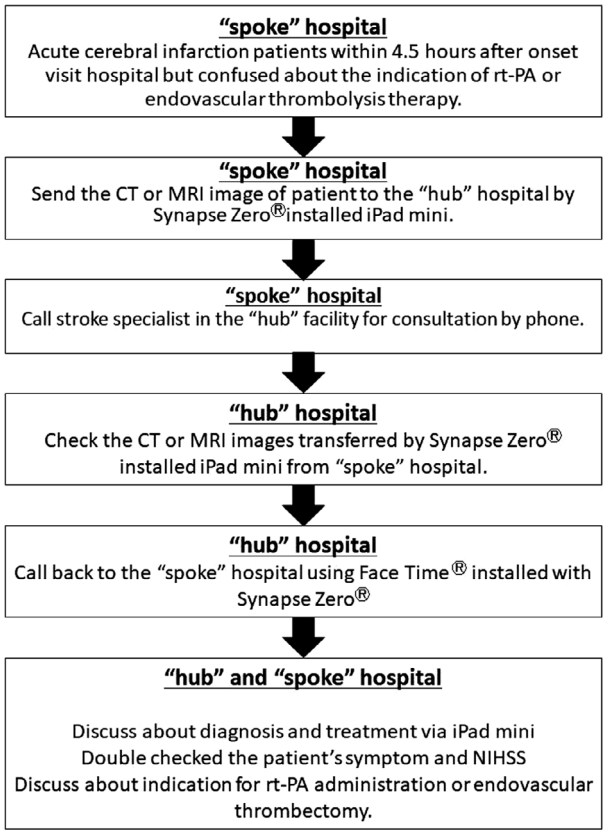

Fig. 2. Flowchart of the telestroke support procedure.

Evaluation of the effect of the telestroke system on shortening time to start rt-PA therapy

We evaluated the effect of this telestroke system on shortening time from onset to starting rt-PA therapy. Specifically, we compared the time from emergency call to arrival at spoke hospital with the estimated time from emergency call to arrival at a nearby stroke center by ground ambulance calculated using Google Map (Google LLC, Mountain View, CA, USA). We also calculated the estimated time from the landing point of physician-staffed helicopter to the nearby stroke center by Google Map and compared the data.

RESULTS

WE SELECTED THREE hospitals as the "spoke" hospitals and one as the "hub" hospital. The location of "spoke" and "hub" hospitals and their relation to one another are shown in Figure 3. The average distance from a "spoke" hospital to their nearest stroke center was 46.1 ± 12.6 km and average time for emergency ground transportation was 47.6 ± 3.21 min.

From May 2017 to November 2018, the telestroke system was initiated for seven patients (male, $n = 5$) who had an average age of 77.2 ± 6.3 years. The patients' main symptoms were hemiparesis ($n = 4$) and consciousness disturbance ($n = 3$). Among the seven patients, five were diagnosed with acute cerebral infarction, one with intracerebral hematoma, and one with brainstem encephalitis. In the patients diagnosed with acute cerebral infarction, three received intravenous administration of rt-PA by the general physician under this telestroke support system (Table 1). In these patients, the average time from arriving at the "spoke" hospital to starting rt-PA administration was 70 ± 7.7 min, with the average time from stroke onset to rt-PA administration being 210 ± 43.5 min. In these cases, time from emergency call to arrive at the "spoke" hospital was 106.6 ± 41.1 min. Otherwise, the estimated time from emergency call to arrive at the nearby stroke center by ground ambulance was 185.8 ± 48.5 min. Furthermore, considering that the landing point of physician-staffed helicopter was not in the vicinity of the spoke hospital, it was

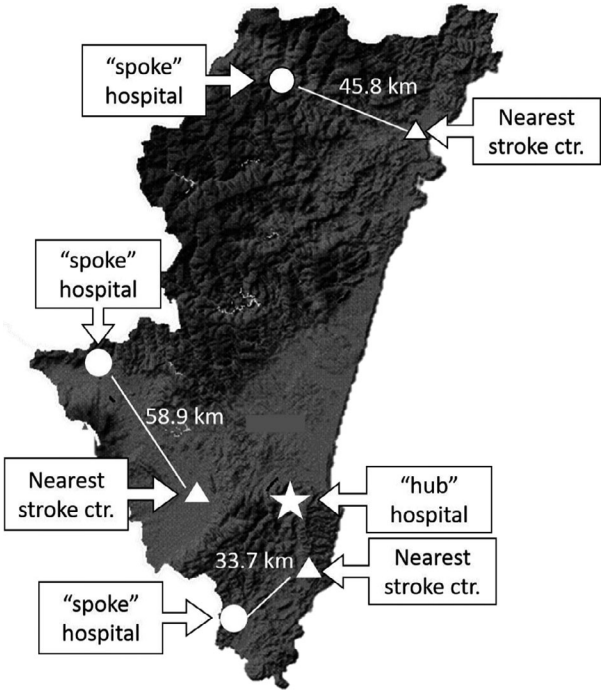

Fig. 3. Location of the "spoke" and "hub" hospitals, and distance from the "spoke" hospitals to their nearest stroke center.

estimated that it would take approximately 26 additional minutes to transport the patients to a nearby stroke center by a helicopter compared with when they were transported by ground ambulance to the spoke hospital. In one patient, a dramatic improvement of symptoms was observed; however, symptoms did not improve in the other two patients.

DISCUSSION

IN THIS STUDY, our telestroke support system encouraged general physicians, who did not have a stroke center, neurosurgeons, or neurologists nearby, to promptly administer rt-PA to patients with acute cerebral infarction, and as a result, the time from onset to starting rt-PA therapy was shortened by 45 min by transporting patients to the "spoke" hospital. To improve the prognosis of patients with acute cerebral infarction in areas without access to a stroke center, or stroke specialists, general or emergency physicians in core emergency hospitals need to be able to perform rt-PA treatment as soon as possible. This concept has not been limited to acute cerebral infarction. For example, telemedicine support systems for general physicians have been used in some remote islands.[12] However, as we mentioned before, most currently used telestroke systems in Japan were intended to support neurosurgeons or neurologists who do not specialize in stroke management. Therefore, a telestroke system aimed at providing support for general physicians was rare.

In recent years, the deployment of physician-staffed helicopters (i.e., doctor helicopters) as part of Japan's emergency medical system has advanced. It may be speculated that the time from stroke onset to the administration of rt-PA can be shortened by directly transporting a stroke patient to a stroke center by a doctor helicopter. However, doctor helicopters cannot operate at night or in bad weather. Furthermore, in case of this study, the areas where the "spoke" hospitals were located were in mountainous areas, where there were no landing points for the doctor helicopter in the immediate vicinity of where patients were located. In addition, road development was lacking in these areas, and it usually took considerable time to transport the patients to the landing point. This was the motivation for implementing this telemedicine support system.

Although this study included a limited number of cases, the average time from emergency call to the administration of rt-PA was 210 $\pm$ 43.5 min, with the average time from arriving at the hospital to the administration of rt-PA being 70 $\pm$ 7.7 min. Although it is an estimation based on calculation from Google Maps, if these cases were transported by ground ambulance to a nearby landing zone and then transported to a nearby stroke center by a doctor helicopter, it would have taken approximately 26 additional minutes compared with ground ambulance transportation to a "spoke" hospital. Moreover, it would have taken an additional 45 min to directly transport a patient to a stroke center by ground ambulance. Considering the geographical landscape where the "spoke" hospitals were located, which limited the ability for doctor helicopters to land nearby, implementation of telestroke might be necessary.

In developing this system for general physicians, we thought that it essential to include functions that allowed specialists to verify and observe neurological symptoms, NIHSS evaluation, and drug administration, in addition to reviewing CT images, for them to determine the indication of rt-PA or endovascular treatment. We further thought that enabling real-time discussions using a videophone system was essential for the general physicians to be able to consult with a specialist face-to-face. Furthermore, Isahaya et al.[13] reported that there was no difference in the accuracy of evaluating the NIHSS score whether using a video transmission system or face-to-face with the patient. Taken together, a telemedicine device with a thin client viewer system plus videophone was a useful and practical tool for stroke telemedicine.

When implementing telestroke devices, the issue of cost cannot be avoided. The most expensive aspect of typical

Table 1. Summary of cases with acute cerebral infarction

Age	Sex	Symptom	Diagnosis	Rt-PA treatment	Time from onset to starting rt-PA	Time from arriving at the "spoke" hospital to starting rt-PA therapy	Transport to the "hub" hospital after induction of rt-PA therapy	Outcome
74	Male	Left hemiparesis	Acute brainstem infarction	Yes	160 min	74 min	Yes	Symptom unchanged
76	Female	Left hemiplegia	Acute cerebral infarction, right MCA territory	Yes	240 min	60 min	Symptom unchanged	Yes
84	Male	Consciousness disturbance	Acute cerebral infarction, left MCA territory	No	—	—	—	Symptom unchanged
70	Male	Right hemiparesis	Acute lacunar infarction, left internal capsule	No	—	—	—	Symptom unchanged
85	Male	Left hemiparesis	Acute cerebral infarction, right MCA territory	Yes	230 min	76 min	Yes	Symptom disappeared

MCA, middle cerebral artery; no, no rt-PA treatment; rt-PA, recombinant tissue plasminogen activator.

systems is the cost of installing a server. To reduce the cost, we built a system that used existing servers in "spoke" hospitals. Images were converted to JPEG and uploaded automatically to the server already installed at the "spoke" hospital.

As for the safety of using the telestroke support system, Pervez et al.[14] compared the effectiveness and safety of rt-PA therapy in patients with acute ischemic stroke administered at stroke centers and at nonstroke centers via a telestroke system, concluding that there were no significant differences in treatment efficacy, complication rate, or effectiveness. In our study, there were no severe complications from performing rt-PA therapy at the "spoke" hospital. However, should a complication occur, there is the issue of who is responsible for diagnosis and treatment. In our system, final responsibility for diagnosis and treatment lies with the general physician at the "spoke" hospital. Ultimately, the decision to administer rt-PA was made by the general physician at the "spoke" hospital. As there was concern that the use of this telemedicine system would decrease if the "spoke" hospital assumed responsibility for the final treatment, patients who were administered rt-PA with the support of telemedicine in the "spoke" hospital were immediately transferred to a "hub" hospital, and a specialist provided for further treatment. In general, with larger numbers of patients, the patients would be transported directly to stroke centers (located far from the area) instead of being initially treated at the "hub" hospital. Therefore, further improvement of the entire system is necessary.

Finally, there are limitations in this study. As the number of target cases was small, we were able to demonstrate that the time from onset to rt-PA administration was shortened, but it was not possible to examine whether this ultimately led to an improvement in prognosis. Therefore, it is necessary to continue studying this point in future cases.

CONCLUSION

FOR AS MANY patients with acute cerebral infarction who are in areas without a stroke center or stroke specialists to benefit from rt-PA therapy, we implemented a new telestroke support system for general physicians located in these areas. Here we demonstrated that using this system shortened the time from stroke onset to the administration of rt-PA by 26–45 min, which would be the time if patients were directly transported to stroke centers.

DISCLOSURE

Approval of the Research Protocol: The protocol for this research project was approved by a suitably comprised institutional Ethics Committee and conformed to the provisions of the Declaration of Helsinki (Committee of University of Miyazaki, Approval No. 2015-091).
Informed Consent: Informed consent was obtained from the patients or guardians in an opt-out model involving publicity documents.
Registry and the Registration No. of the Study/Trial: Not applicable.
Animal Studies: Not applicable.
Conflict of Interest: None declared.

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